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## DEHYDRATION, EVACUATION, AND CHARGING AS RELATED TO THE COMPRESSOR

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Because of the inherent complexities of a refrigeration system, proper processing is critical. Not only must close tolerances and fits be met, as is normal to many manufacturing cycles, but the chemical, electrical, and mechanical parts of the system must be processed so that they will remain compatible over an extremely long life. There are three processing techniques peculiar to the refrigeration industry; Dehydration, Charging, and testing. It is the inter-relationship of these processes with the compressor that concerns us here. The refrigeration unit designer is faced with the task of putting together a number of wet components into a reliable (dry) system. To do this he must specify dehydration processes and moisture limits on the component parts. The reliability of the final product depends on the outcome of these processes and the true value of their limits.

The compressor design engineer must ease this process by producing an easily dehydrated and evacuated compressor. Given this, the process engineer can endeavor to give consistent results with economic methods. With consistent processing results, the unit designer can correlate moisture and non-condensable data with life tests and field results to arrive at a reliable product. There are many pitfalls on this path.

In mass production of refrigeration systems, it is generally best to dehydrate component parts, including the compressor, before assembling the system. Problems are then easily isolated and controlled while final dehydration is reduced to an evacuation.

Proper dehydration of the components will remove many things besides water, solvents, acid fumes, drawing compound and many unimaginable inadvertent contaminants. But, the real purpose of the compressor dehydration process is to reduce the equilibrium moisture content of the compressor to an amount that will give a reliable system; one that will not freeze-up, burn out, stick, or otherwise fail.

Three methods are in general use. One is the hot air method in which the compressor is heated in an oven while dry air is passed thru the compressor and over the motor windings. Another is the open air method in which the compressor sub-assembly and the unwelded housing parts are passed thru a hot oven with a low dewpoint atmosphere. A third method is heating the compressor while under vacuum.

In the hot air method of dehydration, a small current of air is passed thru the housing and over the motor while it is hot. By the nature of things this flow cannot be very large. Less than .25 CFM is common. Temperatures are on the order of 280°F to 300°F. This doesn't give any great driving force to move vapor out of the pockets and labyrinth of the motor windings. Consequently, the process takes time. Eight to sixteen hours in the oven may be necessary, depending on the size of the compressor and particularly the motor. At mass production rates this calls for considerable investment in ovens, and oven maintenance. This system is capable of very good dehydration results. However, any defect in oven temperature control or circulation which allow undetected cold zones will give erratic results.

In the open air method of dehydration, the motor windings and other parts are much more exposed to circulating hot air which of necessity must have a controlled dewpoint. A +20°F or lower dewpoint is used. This method allows a shorter cycle or a smaller oven. It also requires continuous operation of the oven, positive pressure in the oven, and a "Kathabar" or similar air drying system. The controls and instrumentation are elaborate. The process has one peculiarity; the compressor must be welded, painted, and leak tested after the dehydration. If it leaks, re-dehydration after repair is a problem requiring another system or another set of standards.

The heat and vacuum method is perhaps faster than either of the other two methods. Although the time required will depend on the heating rate of

the internal parts of the compressor while under vacuum, that is limited convective heating. This system demands good maintenance and engineering and a good knowledge of vacuum technology, which is not common. In operation of this dehydration system, a large number of compressors are manifolded onto one vacuum pump system and exhausted to a pressure on the order of .1 torr or 100 microns.

None of these systems will work properly if there are moisture traps built into the compressor. These may be cul-de-sacs behind check valves which will not open under the pressures involved, although they function perfectly in the finished system. Small tubes, tiny passages or close fits when full of oil may trap moisture. Some very odd appearing valves are used in compressors to bypass or vent these traps.

All of these systems are designed to handle the normal moisture in a normal compressor. Depending on the size and materials of construction, this will be a few grams. In a fractional H.P. compressor with "Mylar" rather than paper slot and interphase insulation, it should be less than 1 gram. One of the peculiarities of this business is that the normal moisture of the stator varies with the season. Going up in May, June, July and August. It apparently follows the absolute humidity.

If the hot gas method, or the heat and vacuum method, is given an excessively wet compressor, one full of water for instance, the unit will not be properly dehydrated. In the heat and vacuum system, the whole manifold will not pull down. This condition, excessive water in the compressor, can arise from freak conditions in the leak test tanks, washing, or any submersion of the compressor in water. For example, a compressor charged with 300 psi air pressure has a large leak in an external tube. If the air pressure must seep through tight fits to fill the tube, the results will be an occasional large bubble which the inspector may or may not see. If the leak were small, the result would be a continuous stream of small bubbles easily seen. If the large leak is subsequently repaired, water may easily be left in the tube. Wet leak test air can soon saturate windings and surfaces and may even leave liquid water behind when the pressure is suddenly relieved. These conditions can throw unexpected loads onto a dehydration system not designed to handle it. None of these systems however, have any built-in test, quick 100% check that will tell the operator when the system is O.K.

Whatever the method of dehydration, the method of checking for moisture after dehydration is generally the same. The centrifuged cold trap. There are other methods but this method is adapted to factory use and is fast enough to run on one 8 hr. shift. In this method a compressor is heated in a 300°F oven while a vacuum is pulled on it thru a cold trap (dry ice). After a fixed time, 3 or 4 hrs., the trap is cut-off, warmed to room temperature and removed from the

system. The liquid is then centrifuged into a graduated section where it is visually estimated. The test is strictly empirical and has no value unless run regularly. But if it is run daily with care it gives an excellent check on the operation of the dehydrated system. Any change or variation in the time in the oven, the heating rate of the oven, the heating rate of the internal parts, and the pumping speed of the vacuum system, will effect the amount of moisture removed. Therefore, correlation of tests run at different plants is not preferred. If the test is run for a longer time or at a higher temperature more water will be produced. The total available moisture may be almost twice what the test shows. Here is the moisture recovered from one stator, (not a compressor), by a vacuum cold trap.

#### Moisture

1st. trap (4 hr., stator at room temp)	.20 CC
2nd. trap (4 hr., stator at 300°F)	.30 CC
3rd. trap (4 hr., stator at 400°F)	.18 CC
4th. trap (12 hrs., stator at 400°)	.17 CC
TOTAL	.85 CC

Histograms on the results of some of these tests are shown in Figures 1 & 2. It will be noted that the distribution is not normal.

Specifications on dehydrated compressors, sold to the trade are generally 180 milligrams moisture by the centrifuged cold trap method. The moisture in dehydrated compressors as produced is considerably lower than this and depends on the size of the compressor. Fifty milliliters for fractional H.P. compressor might be considered a fair average. The deviation from this average depends on a number of things including the season of the year.

Whatever the specification, the compressor must be evacuated to low non-condensable pressure in a minimum of time so that it can be charged. If the moisture content of the compressor is high, the vacuum system will not be able to reduce the pressure to a satisfactory level. If the unit is charged anyway, it will not perform satisfactorily. That is, it will not meet the capacity requirements. This non-condensable pressure is usually checked by measuring the pressure at the charging board. The unit is connected to the charging board vacuum gage by a hose, the hose is evacuated, and a valve at the unit is opened. If the pressure rise in a specified time exceeds a specified pressure, the unit is rejected and the board will not charge.

The unit is usually leak tested under air pressure (150 psig is a UL requirement) just before evacuation. This high pressure can be trapped in the motor laminations and possibly elsewhere so that it is not all removed by evacuation. If the unit is sealed after evacuation, the pressure is not read by the vacuum check unless there is a delay between evacuation and charging such as an overnight shutdown. This residual pressure is the actual non-condensable pressure that the operating refrigeration system will have as long as it

operates. Since the moisture content of the compressor influences the pumping speed of the evacuation system, the non-condensable pressure in the system will be influenced by the moisture level of the compressor. A second evacuation pump is sometimes provided just before the charging boards so that compressors which have been allowed to stand overnight after normal evacuation can be re-evacuated. This avoids charging board rejects during start up after shutdown. Sometimes the charging board is placed so close to the evacuation pumps that there is no trouble of this nature. However, the residual non-condensables are still in the unit.

The charging board vacuum check provides for inspection of the unit for moisture and non-condensables. This is unfortunate since the machine was designed to charge the unit - not inspect it.

Finally; consider the cost of dehydration and evacuation or even discharge, re-evacuation and re-charge in the plant as compared to the cost of doing it in the field. If the cost of replacing a compressor in the field is \$100, then one cent per unit spent on dehydration that will reduce the rate of field failure by 0.1% will save \$100 per 1000 units produced.

In summary; the compressor designer must consider the dehydration and processing of his design so that it can be efficiently and reliably processed. The unit designer on the other hand must be aware of the effectiveness of the dehydration and evacuation processes and more important be aware of the limitations, if any, of moisture tests. To quote the ASHRAE handbook, "Improved designs or clever innovations can be completely nullified by archaic or careless factory procedures."







